Enzymatic treatment as an alternative to carbonization of disperse/reactive dyed polyester-cotton blends

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Polyester-cotton fabrics having different blend proportions were dyed with various disperse, reactive and disperse/reactive combination dyes and then treated with cellulase enzyme as an alternative to carbonization. This resulted in the removal of reactive dyed cotton portion of the blends, thereby altering the λw towards disperse dye. The trend of the enzymatic action was almost similar for all the blends, irrespective of cotton content. In case of cotton-rich blends, the traces of cotton were found after the normal enzyme treatment. This was revealed on comparing the results with those of carbonized samples. The fabrics were, therefore, given more severe enzymatic treatment to remove the traces of cellulose. It has been found that severe enzymatic treatment can provide an alternative to carbonization and that it is fully eco-friendly process. A controlled dose of enzyme can be used in the correction of shades for disperse/reactive dyed polyester-cotton blends.

Keywords: Carbonization, Cellulose, Disperse dye, Enzymatic finishing, Polyester-cotton blends, Reactive dye, Thermosol technique

1 Introduction

Biotechnology has already made a significant impact on the textile dyeing and finishing industry. Enzymes, the most familiar bio-active agents employed by the textile industry, are being used in desizing process for many years. More recently, cellulase enzymes have been put to use in finishing.

Cellulases are available to the textile industry from at least 12 different sources and are usually classified on the basis of pH range in which they are most effective. Acid stable and neutral stable are the categories that are effective for textile applications. Cellulases are multi-component enzyme systems commonly produced by soil-dwelling fungi and bacteria. These fungi and bacteria produce cellulase during hydrolysis of cellulose to glucose, which is then consumed as a nutrient. Cellulase is a complex mixture of endoglucanases (EGs), cellobiohydrolases (CBHs) and cellobiases (CBs). EGs cause random hydrolytic chain scission at the most accessible parts of cellulose chains, CBHs split the cellobiose from cellulose ends and CBs hydrolyze cellulose to glucose.

The treatment of cotton with cellulases is well known for fibre surface modification. In fact, a controlled cellulase hydrolysis gives the clean fibre surface from microfibrils. The cellulase enzyme, being a bio-catalyst, offers advantages, such as energy savings through lower treatment temperatures of 40-50°C, low environmental impacts by avoiding the use of chemicals, and low cost by using only the catalytic amount. Better use of cellulase enzymes can be an answer to the desire for both cleaner and less polluting textile technology and high-grade goods with added value.

Commercial-scale biopolishing processes for cellulosic as well as polyester/cellulosic fabrics have been reported recently, where the basic factors influencing the processes are the enzyme concentration which depends on the liquor ratio, and the resulting percentage of treatment product on the weight of the goods, which varies according to the substrate. The biopolishing processes produced different touches and appearances for a diversity of fashionable end-uses, with considerable reliability and, above all, reproducibility. In the present work, polyester-cotton fabrics with different blend proportions have been dyed with various disperse, reactive and disperse/reactive combination dyes and then treated with cellulase enzyme as an alternative to carbonization.
2 Materials and Methods

2.1 Materials

2.1.1 Fabrics
Polyester-cotton (67/33) blended fabric, supplied by The Mafatlal Fine Spinning and Manufacturing Co. Ltd, Navsari, and polyester-cotton (65/35 and 52/48) blended fabrics, supplied by Soma Textiles and Industries Ltd, Ahmedabad, were used.

2.1.2 Dyes
Different disperse and reactive dyes, supplied by Atic Industries Ltd, Valsad, were used individually and in combinations, such as Combination 1 (C.I. Disperse Red 11 and C.I. Reactive Blue 25), Combination 2 (C.I. Disperse Blue 3 and C.I. Reactive Red 31), Combination 3 (C.I. Disperse Violet 26 and C.I. Reactive Blue 187), Combination 4 (C.I. Disperse Blue 56 and C.I. Reactive Yellow 135), and Combination 5 (C.I. Disperse Red 92 and C.I. Reactive Green 19).

2.1.3 Chemicals
Sodium silicate, supplied by Loba Chemie, Mumbai; sodium acetate, supplied by E. Merck (India) Ltd, Mumbai and acetic acid and sulphuric acid, both supplied by s. d. Fine Chem Ltd, Boisar, were used. All these chemicals were of laboratory reagent grade.
Biowash-PL (acid cellulase), supplied by Biocon India Ltd, Bangalore, and Lissapol 100X, supplied by ICI India Ltd, Thane, were used.

2.2 Methods

2.2.1 Combination Dyeing
The polyester-cotton blended fabrics were dyed by Thermo sol technique using different dye combinations. Dye solution was prepared by mixing 0.5g each of disperse dye and reactive dye and the mixture was diluted to 100 ml. Each dyed fabric was then padded thrice through the solution on a padding mangle, dried at 70°C and thermofixed at 180°C for 1min. The fabric was once again padded through a solution of sodium silicate (100° Tw), batched for 24 h, washed, soaked, washed again and dried.

2.2.2 Disperse Dyeing
The fabrics were padded thrice through 0.5% disperse dye solution on a padding mangle and dried at 70°C and thermofixed at 180°C for 1 min.

2.2.3 Reactive Dyeing
The fabrics were padded thrice through 0.5% reactive dye solution on a padding mangle and dried at 70°C. The fabrics were again padded through sodium silicate solution (100° Tw), batched for 24 h, washed, soaped, washed again and dried.

2.2.4 Enzymatic Carbonization
Acid cellulase (1% w/w) was applied on the blends, keeping the material-to-liquor ratio at 1:5 and pH at 4.5-5.0 using sodium acetate/acetic acid buffer at about 40°C. The samples were then kept in polythene bags for two days at 40°C, washed thoroughly with Lissapol 100X at boil and dried. The above procedure was repeated five times. In the case of cotton-rich blend (52/48 PIC), 1.2% (w/w) enzyme was applied two more times to remove the cotton part completely.

2.2.5 Carbonization of Dyed Samples
The dyed samples were carbonized with 70% (w/w) sulphuric acid for 2h at room temperature to remove the reactive dyed cotton part completely. The samples were washed thoroughly and dried.

2.2.6 Analysis of Samples
All the samples were analyzed by measuring K/S on Spectroflash SF 300 Computer Colour Matching system by Datacolor International, USA.

3 Results and Discussion
The disperse and reactive dye combinations were selected on the basis of a considerable difference in their $\lambda_{\text{max}}$. The combination of two different colours produced a third colour and by the enzymatic treatment, the cotton part was removed considerably. This ultimately resulted in reduction in the reactive dye content on the fabric, tilting the $\lambda_{\text{max}}$ towards the disperse dye.

Table 1 shows that the $\lambda_{\text{max}}$ values for the dye combinations 2 and 4 (560 nm and 400 nm respectively) are the same as that for the reactive dyeings. But in case of combinations 1, 3 and 5, a totally different $\lambda_{\text{max}}$ is obtained, leading to a tertiary colour. The $\lambda_{\text{max}}$ value of 680 nm in case of combination 1 is higher than those in case of combinations 3 and 5. The $\lambda_{\text{max}}$ values for combinations 3 (590 nm) and 5 (560 nm) fall in between the values for disperse and reactive dyes respectively.
The enzyme-treated samples for all combinations and carbonized samples show that their $\lambda_{\text{max}}$ values are similar to those of their respective disperse dyed samples. The $\lambda_{\text{max}}$ value of enzyme-treated samples in case of combination 5 (530 nm) is found to be the same as that of individual disperse dyeing, whereas carbonization made a change in hue of the disperse dye, leading to a $\lambda_{\text{max}}$ of 520 nm. The study reveals that by the application of enzymes on blended fabrics of two different combination colours, $\lambda_{\text{max}}$ can be altered without using environment-polluting chemicals, such as conc. sulphuric acid.

Table 1 shows that in case of disperse dyed samples the $K/S$ value decreases with decrease in polyester content in the blend. In case of combination 1, disperse dyeing produced a value of 1.1381 for 67/33 blend while the values were 1.0311 and 0.9445 respectively for 65/35 and 52/48 blends. A similar trend is observed in the case of other combinations. However, a reverse trend is observed in the case of all the reactive dyed samples, where the $K/S$ value increases with the decrease in polyester content, eg the $K/S$ values are 1.1537, 1.5754 and 2.1984 respectively for 67/33 65/35 and 52/48 polyester-cotton blends in the case of combination 1. All the other combinations also show a similar trend. In the case of disperse/reactive dyed fabrics, the $K/S$ values increase with the increase in cotton content in the blends, eg 1.3724, 1.4774 and 2.0643 for 67/33, 65/35 and 52/48 polyester-cotton blends respectively in case of combination 1.

A close comparison of the $K/S$ values for enzyme-treated and carbonized samples reveals that the values are comparable for 67/33 and 65/35 polyester-cotton blends, indicating that the removal of cotton in both the cases is similar. However, in case of 52/48 polyester-cotton blend, the $K/S$ value of enzyme-treated sample is found to be rather higher than that of respective carbonized sample for all the combinations. This may be due to the possibility of traces of cotton (with respective reactive dyed shades) remaining on the enzyme-treated samples, possibly because of the initial higher cotton content in polyester-cotton fabrics. The conventional carbonization process being more powerful, such residual cotton may not be left out on the carbonized samples. It was, therefore, thought to give an additional but more severe enzymatic treatment to 52/48 polyester-cotton blends.

The additional enzymatic treatment under severe conditions removed the remaining cotton content and brought the higher $K/S$ values to the level of that of the carbonized sample for all the combinations. The new enzyme-treated sample’s $K/S$ value in case of combination 1 (1.0962) is at par with that of the
Fig 1—Comparison of $\lambda_{\text{max}}$ of shades dyed on polyester-cotton blends with C.I. Disperse Red 11 and C.I. Reactive Blue 25 combination (A—disperse dyed, B—reactive dyed, C—disperse/reactive dyed, D—enzyme treated, and E—carbonized) carbonized sample (1.0958). A similar trend is observed in all other cases.

A typical comparison of the $\lambda_{\text{max}}$ of various substrates in the case of combination 1 (Fig. 1) shows that the $\lambda_{\text{max}}$ values are 540 nm and 610 nm respectively in case of disperse and reactive dyed samples, and combination of both the dyes produces a higher value (680 nm) than those of individual disperse and reactive dyeings. The enzyme-treated as well carbonized samples show the $\lambda_{\text{max}}$ values of 540 nm, the $\lambda_{\text{max}}$ of disperse dye, ascertaining the removal of reactive dyed cotton part. A similar trend is observed in the case of other combinations.

4 Conclusion

Disperse and reactive dyeings of varying $\lambda_{\text{max}}$ on polyester-cotton blends produce a tertiary colour. The enzymatic action on the dyed samples alters the $\lambda_{\text{max}}$ towards the disperse dyes. The K/S values of enzyme-treated and H$_2$SO$_4$-carbonized samples indicate that the action of enzyme is almost uniform on all the blends, irrespective of the cotton content. An additional enzymatic treatment on 52/48 polyester-cotton blend removes the entire cotton portion, which is manifested as the decrease in K/S values to the level that of H$_2$SO$_4$-carbonized samples. This technique can successfully be implemented for the removal of cotton as an alternative to carbonization as well as in the correction of shades for disperse/reactive dyed polyester-cotton blends by carefully optimizing the dose of enzyme application.

References